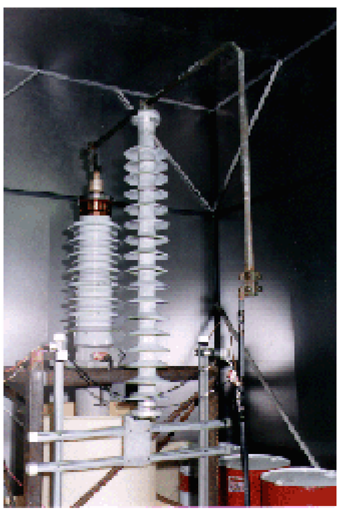
A Different Kind of Downsizing

Power Systems, INEEL—At up to one-hundred thousand times smaller than the equipment it is designed to replace, the Electro-Optic High Voltage Sensor, developed by an interdisciplinary team of engineers and scientists at INEEL, promises to transform the way high-voltage electricity is measured and monitored. It is smaller, cheaper, more efficient, and because it doesn't contact high voltage sources directly, much safer than conventional monitoring systems.

Where I see the greatest use is in old big cities. It can cost a million dollars to put a [potential transformer] in a subway in New York City.
—Gary Seifert

The EOHV Sensor, now available for licensing, recently earned INEEL engineers James Davidson, Gary Seifert, and Thomas Crawford an R&D 100 award, a prize given annually by Research & Development Magazine for innovations signifying "quantum leaps in technological improvement". It was one of three 1998 R&D 100 awards that were presented to INEEL researchers.



These large ceramic inductors top off potential transformers. The EOHV Sensor is attached to the pole on the right.

FOUR CRYSTALS + THREE OPTIC LINES = ONE SAFE SENSOR

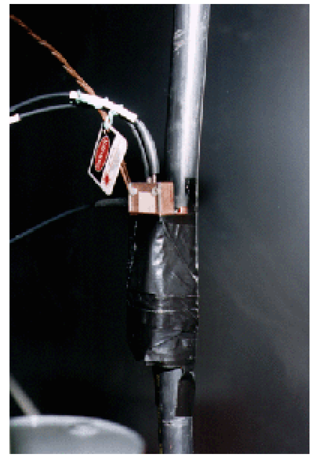
The pen-sized sensor represents a radical departure from the potential transformers now used in power metering. The size of a small car, the largest of these mammoth potential transformers cost more than $100,000 and are topped off with six, three-foot inductors.

In contrast, the $5,000 EOHV Sensor consists of four crystals packed in a ceramic rectangular case a few inches long. Three fiber optic cables slither from the case to electronics "the size of a kid's lunchbox," according to Project Manager Gary Seifert.

And potential transformers pose another problem. Since they are contiguous with the electrical circuit, they threaten to electrocute workers who install or maintain them.

Unfortunately, danger comes with a potential transformer. Like a middleman, it steps the high voltages on powerlines down from 135 kiloVolts to about 115 Volts, where an attached electro-mechanical device can measure it. (For comparison, the voltage in a typical electrical outlet weighs in at 120 Volts.)

The EOHV Sensor cuts out the middleman. The high voltage on the power lines doesn't need to be stepped down. And since electricity gives off an electric field, the sensor head sits within that field—the electricity doesn't run through the sensor. The electronics that control the sensor can be hundreds of meters away from the hazardous voltage—as far away as the fiber optics cables will run.

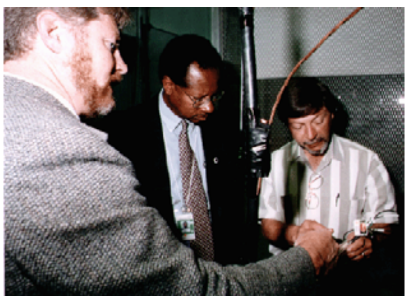


Testing the EOHV Sensor requires attaching it to a conductor, which looks remarkably like a pole, near the research lab's transformer (not shown).

Theoretically, said Davidson, the upper limit to the sensor is the voltage at which the internal crystal will crack. The highest source they've tested loomed at about 129 kiloVolts, but they think they can go higher. Typical lines they'll encounter, said Seifert, run anywhere from 5 to 750 kiloVolts.

And besides, the voltage across the crystal isn't the same as the voltage of the power source. The electric field's strength drops off fast with space between the sensor and source.

In any event, they haven't cracked a crystal yet.



Project manager Gary Seifert (left) and staff engineer Jim Davidson (right) show Lockheed-Martin VP Bill Guyton how the EOHV Sensor works.

POTENTIAL, POTENTIAL, POTENTIAL

With a $1 billion potential transformer market in the U.S., the potential opportunities for the sensor are numerous. The unobtrusive device could be installed in place of new potential transformers. It could replace old ones that get worn out. Or it could be used in areas where a potential transformer would be hazardous or just wouldn't fit.

"Where I see the greatest use," said Seifert, "is in old big cities. It can cost a million dollars to put a [potential transformer] in a subway in New York City, and it would be the size of a Volkswagen."

While the EOHV team is developing the sensor for metering, more exciting is its capacity for power quality monitoring. Continuous power quality is "one measurement that's not being made because nobody knows how to do it," said Jim Davidson, the INEEL staff engineer who has nudged the project along in lean times. Now, when there may be a problem with power quality, power system engineers bring temporary equipment in and remove it when they are finished. The movement of the equipment and the downtime during set-up and removal are costs they'd rather not deal with.

Continuous power quality monitoring would detect lightning strikes and other power surges that cause current flow aberrations along the lines—impossible for conventional transformers because they resist changes in current.

The crystals within the EOHV Sensors, on the other hand, respond easily to such variation. Because the sensors are small and inexpensive, they can be installed almost anywhere, remain on the lines permanently and monitor power quality continuously.

Constant monitoring is especially important with utility deregulation—various power sources need to be incorporated into the main power grid. "Power companies need to know what their power quality is," said Davidson. "If I'm the power company and there is a dispute from the consumer, I need to know if and who screwed it up in the distribution."

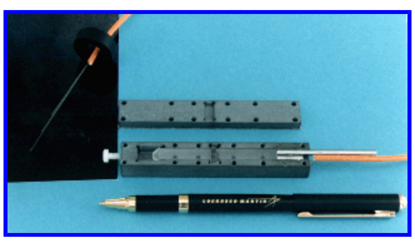
Beyond the power industry, the EOHV Sensor could be applied wherever engineers need to measure an electric field, such as in microwave and radar applications.

TAMING OF THE POCKELS CELL

Davidson (left) and Seifert all decked out at the awards ceremony.

Simplicity is the sensor's virtue. Positioned within a few inches of transformers or other power sources, the internal crystal responds to the electric field generated by the electricity. "The strength of an electric field is based on the strength of the voltage," said Davidson, "like the strength of a magnetic field is based on the strength of a magnet."

Some crystals change their refractive properties when exposed to an electric field in a manner known as the "Pockels Effect". A crystal like that, called a Pockels cell, is the key to the sensor's function. A polarized beam of light traveling through the Pockels cell gets rotated by the cell's electric field-altered inclination to refract. How much the light rotates, ultimately, depends on the electric field's strength.



The EOHV Sensor is sleek, sleek, sleek. Click on the figure for more details on how the sensor works.

Fiber optic cables bring the polarized light to the sensor head and draw the rotated light back to the electronics anywhere from a hundred (in the electronics lab) to thousands of meters away. There, the electronics convert the light signal into a voltage measurement.

With ampere meters set alongside the EOHV Sensor, power quality—which is a combination of voltage and current—could easily be monitored.

Engineers have been trying to develop optics for measuring voltage for many years, said Seifert. The Pockels effect is well known, and enough crystals exhibit it that it was only a matter of time before someone would tame it to do the engineers' bidding.

by Mary Beckman, INEEL Research Communications
September 1998

For more information about the EOHV Sensor, contact Program Manager Gary Seifert with the Power Systems group, Staff Engineer Jim Davidson or LMITCO Technology Transfer Officer Thomas Ulrich. The third winner of the EOHV Sensor team is Thomas Crawford, now at Optical Physics Technologies.

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